LITERATURE ON RIVER GANGA: A BIBLIOMETRIC ANALYSIS

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River Ganga is globally famous not only because of its historical significance but also for its religious values for a majority of population of Hindus in India and elsewhere in the world. The purpose of this study is to conduct a Bibliometric analysis of the published research articles on River Ganga for the period of 25 year (from 1991 to 2016), using Science Citation Index expended. The parameters used in the present bibliometric research include document types, language, categories, journals, countries, keywords, authorship and other related issues. Results of the study revealed that India is the top contributor in terms of total publications followed by USA. The impact of countries, institutions, and authors was assessed by TC2016. The authors with highest contributions were mainly from India, and few were of France, and Bangladesh. Indian institutes also retain the top position in terms of article contribution, most prolific institutes are: Indian Institute of Technology, Lucknow University. Additionally, keywords analysis was also done in order to know about the research interests, which most likely specified considerably vast difference in research focuses.

Keywords: Ganges; Ganga; River; Bibliometric Analysis.

INTRODUCTION

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The Ganga is valued globally not only as one of the major rivers but also because of its holiness for a majority of population of Hindus in India and elsewhere in the world. It originates as Bhagirathi from the Gangotri glacier in Uttar Kashi district of Uttaranchal at an elevation of 7010 m. From its source to mouth Ganga River, it covers a distance of 2525 kilometres, and by discharge occupies third place among the largest rivers of the world [1]. The River Ganga is coupled by several tributaries, on its way to its end point; it passes through five states of India.

Hindus consider it not just a river but ''a mother, a goddess, a tradition, a culture,'' worshipped by millions of people. Besides the religious value, Ganga has a great historical significance also, as many former provincial or imperial capitals had been located on its banks. From Antiquity, Ganges and it's all other streams, have been utilized for the irrigation purposes forming key source to agricultural economy of both India and Bangladesh [2].

With all its History of Grandeur and holiness of 5500 years apart, last four to five decades has been a period of deterioration and decay of river Ganga, wherein tanneries, dye industries, leather industries have been continually polluting it. Other activities performed along the cities also contribute to the problem of water pollution.

Consequently, Indian government has come up with a number of massive clean-up programmes, as also several organizations like Ganga Mahasabha are trying to breathe a new life into Ganga. Some of the initiatives taken are: "Ganga action plan, National River Ganga Basin Authority (NRGBA), Namami Ganga Programme, Ganga Manthan" and many others. Even the Supreme court of India has been instrumental for shutting down several pollution prone industries and relocating them to other places. Meanwhile Govt. of India has claimed to raise pollution standards and has already closed more than 100 tanneries, but unfortunately the holy river continues to be desecrated and lot remains to be done in that direction.

In view of religious and environmental issues attached with river Ganga, the present study is an effort to conduct a Bibliometric analysis of the literature published in the same field during the period from 1991 to 2016, which may be useful for study development and management strategy, apart from enhancing its visibility.

METHODOLOGY

For the purpose, the data was extracted from Web of Sciences (WoS), Science Citation Index Expanded (SCI-Extended) database (owned by Clarivate Analytics; formerly Thomson Reuters). During the period under study, 2299 documents were retrieved using the keywords, 'Ganga'' or 'Ganges' in the topic field (including title, abstract, author keywords, and KeyWords Plus) in WoS. Collected Data was downloaded into MS Excel for citation analysis. The type of documents retrieved are: articles, proceeding papers, reviews, note, letters, editorial materials, meeting abstracts, corrections, retracted publications, news items, book chapters and biographical item. Final analysis was, however, done only on articles.

An author designation in the SCI-Expanded is diverse e.g., the "corresponding author" is chosen as the "reprint author". In this article we used the term ''corresponding author''. Author collaboration or association in this article was defined by their addresses. Articles in which authorship is ambiguous, the single author is considered for both first author and corresponding author. Likewise, in case of institutions, the "single institutional" article is considered for both as "the first author institution" and the "corresponding author institution". Other terms that were used for the collaboration patterns "single country articles" (researcher's having addresses from a same nation), "Internationally collaborative article" (articles co-authored by the persons from more than one nations), "single-institution article" (all authors of the article are from the same institution) and "inter institutionally collaborative article" (articles whose authors are from different institutions) [3], [4], [5] & [6]. Articles belonging to England, Scotland, Northern Ireland, and Wales were put under the UK (United Kingdom) [3].

The indicator TC2016, was used to indicate the aggregate number of citations since the article was first published to 2016 [4], [5], [7], [8]. The most important feature of this indicator is that it is an invariable factor in contrast with the index of citations from the WoS [5] & [8]. Another indicator C2016 was also used which denotes the total number of citations in a single year [7] [8].

## RESULTS

Document Type and Language of Publication

The total 2017 articles pertaining to the selected criteria were identified. The overall publications contained 13 document types including articles. Among all the document types, the article type was used most-frequently, covering (2017; 87.73%) of the total publications, followed by proceeding papers (90; 3.9%), Reviews (84; 3.6%), editorial materials (36; 1.5%), letters (19; 0.82%), meeting abstracts (17; 0.73%), notes (13; 0.56%), news item (11; 0.47%), book chapter (5; 0.21%), corrections (3; 0.13%), retracted publication (2; 0.086%), biographical item (1; 0.043%), and addition (1; 0.043%). As journal articles (2017) were majority in number, hence the original ones were identified and then investigated into, while all other types were

discarded. Figure 1 gives the total number of related articles with the citations per article during the period under purview. In the specified period, the increasing trend is witnessed in the number of publications, conversely with the rise and fall in the citations per article, even the lesser number of published articles in 2004 carried the maximum citations per article. Figure 1 shows steady growth in the

number of publications during the recent years, but a reverse trend is also visible in the citations per publication from 2011 to 2016.

From the analysis of total 2017 articles it was revealed that, the maximum numbers of articles comprising of 99.6 % were in English language followed by those in Chinese (0.19 %), Portuguese (0.09 %), Spanish (0.05 %), and French with (0.05 %), respectively.

Figure 1: Ganga related research publications and citations per article 1991-2016
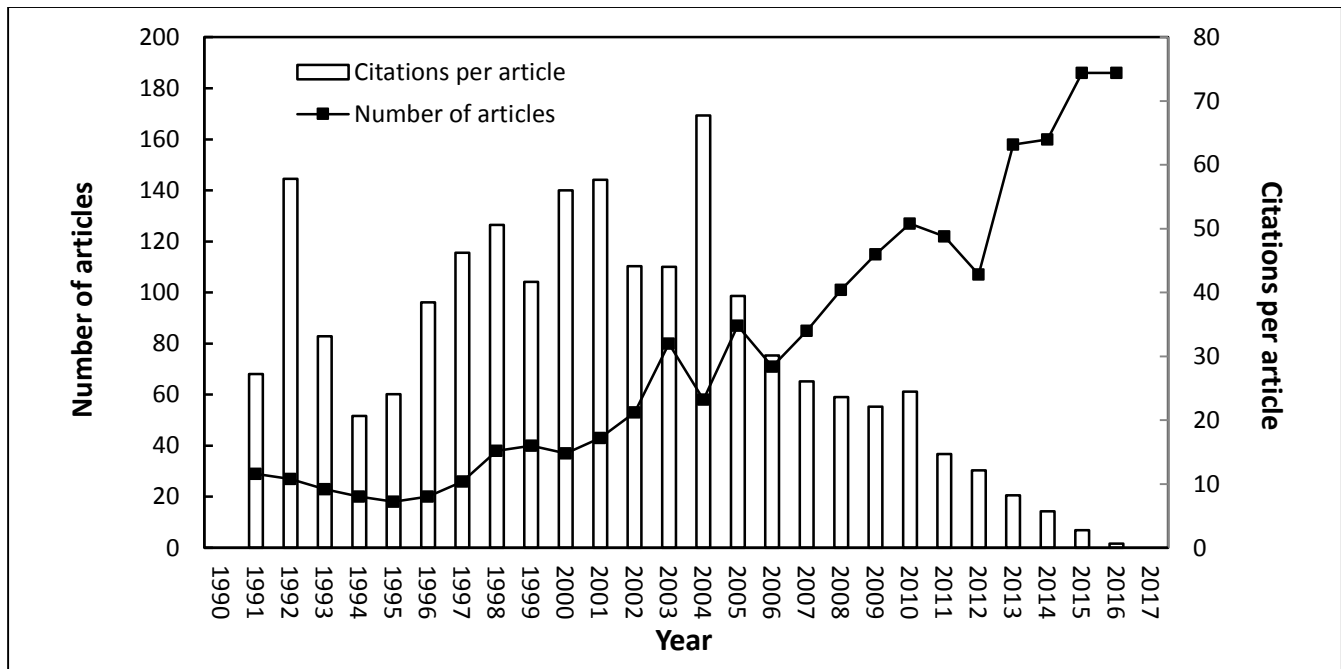
Journal and Web of Science category

A total of 547 journals, reported under 110 WoS subject categories in SCI edition, have published 2017 articles on Ganga from 1991 to 2016. Table 1 provides a list of the top 10 productive journals, which includes Current Science from India taking the first place with 94 articles (4.66%), followed by Environmental Monitoring and Assessment with 61 articles (3.02%).

In addition, there are 287 journals (52.47%) which published only one article, followed by 90 journals (16.45%), and 41 journals (41.50%) which published two and three articles respectively. As reported in

JCR2016 only 1870 articles appeared in the journals having Impact Factor (IF) information.

To check the application of Bradford's Law of Scattering (Bradford 1934), all the journals were put in descending order in terms of the number of articles published by them on the river Ganga. As many as three zones of published output were identified. The 1st zone called the most prolific zone represents 33% of total articles published in 21 journals (3.84%) on the topic under study. Zone 2 carries 33% of total articles published in 87 journals (15.90%), while Zone 3 which represents least prolific zone with 33% of total articles published in 439 journals (80.26%). The distribution of articles

in all the three zones more or less follows the Bradford's law of Scattering. The number of journals was around 1: n: n2 (1:21:212). This illustrates that the river Ganga related study contained 21Bradford's core journals out of 547 journals. Mekong River Study by Sui in 2015 reported that there were 31 core journals in 415 journals. Another study by Wang (2011) revealed that there were 59 core journals in WoS category of water resource. It is evident from the Table 1 that both "Current Science" and "Environmental Monitoring and Assessment" published a good number of articles with 94 (4.66%) and 61 (3.02%) respectively. Among the most productive journals, 'Science' is having the highest Impact Factor (IF2016=4.900) with 25 (1.24%) articles.

Table 1: Most productive journals with the number of articles, impact factor, and Web of Science category of journals in its position

Journal	TP (P)	IF2016	Web of Science category
'Current Science'	94 (4.66)	0.843	Multidisciplinary Sciences
'Environmental Monitoring And Assessment'	61 (3.02)	1.687	Environmental Sciences
'Journal Of The Geological Society Of India'	57 (2.83)	0.479	Geosciences, Multidisciplinary
'Environmental Geology'	45 (2.23)	N/A	Environmental Sciences; Geosciences, Multidisciplinary; Water Resources
'Environmental Earth Sciences'	39 (1.93)	1.569	Environmental Sciences; Geosciences, Multidisciplinary; Water Resources
'Geochimica Et Cosmochimica Acta'	38 (1.88)	4.609	Geochemistry & Geophysics
'Earth And Planetary Science Letters'	35 (1.74)	4.409	Geochemistry & Geophysics
'Quaternary International'	30 (1.49)	2.199	Geography, Physical; Geosciences, Multidisciplinary
'Sedimentary Geology'	25 (1.24)	2.373	Geology
'Science Of The Total Environment'	25 (1.24)	4.900	Environmental Sciences
'Natural Hazards'	25 (1.24)	1.833	Geosciences, Multidisciplinary; Meteorology & Atmospheric Sciences; Water Resources
'Journal Of Hydrology'	24 (1.19)	3.483	Engineering, Civil; Geosciences, Multidisciplinary; Water Resources
'Chemical Geology'	23 (1.14)	3.347	Geochemistry & Geophysics
'Geomorphology'	22 (1.09)	2.958	Geography, Physical; Geosciences, Multidisciplinary
'Journal Of Applied Ichthyology'	20 (0.99)	0.845	Fisheries; Marine & Freshwater Biology
'Geophysical Research Letters'	20 (0.99)	4.253	Geosciences, Multidisciplinary
TP Total articles; *P* the percentage of total articles; *IF2016* impact factor in 2016			

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Table-2 shows that the majority of articles fall under the ten SCI Subject categories. In which Environmental Sciences with 551 (27.32%) articles occupies first position, followed by Geosciences Multidisciplinary with 523 (25.93%), and Water Resources with 344 (17.06%). Similar trend was also shown in the Mekong River research (Sui, Chen, Lu, & Chen, 2015), the only difference was that Water resources and Geosciences, Multidisciplinary were ranked at 2nd and 3rd place respectively.

Table 2. Ten SCI Categories with The Most Articles

SCI subject category in 2016	TP	P
Environmental Sciences	551	27.32
Geosciences Multidisciplinary	523	25.93
Water Resources	344	17.06
Geochemistry Geophysics	180	8.92
Multidisciplinary Sciences	171	8.48
Meteorology Atmospheric Sciences	139	6.89
Geography Physical	117	5.8
Marine Freshwater Biology	95	4.71
Oceanography	80	3.97
Engineering Civil	65	3.22
TP Total Articles; *P* The Percentage Of The Total Articles		

Countries/territories and institutions

Indicators like "independent, collaborative, first author, and corresponding author articles of institutions and countries" (Ho et al. 2010; Wang et al. 2010; Sui et al. 2015) were introduced. Country-wise contribution of published articles was predicted by perusing the location and the association of at least one author. Excepting seven articles found without author address information, the remaining 2010 articles were with author address information, amongst which single country articles were 1340 published by 78 countries and the numbers of internationally collaborative articles were 670 published by 76 countries. Table 3 shows most prolific countries using six indicators namely 'total number of articles'(TP), 'single country articles'(SP), 'internationally collaborative articles' (CP), first author articles (FP), 'corresponding author articles' (RP) and 'percentage of single country articles' (S).

The table shows that India's contribution amounts to 58% approximately, out of total world publications and is ranked 1st among all indicators, followed by USA and Bangladesh with 405 (20.15%) and 177 (8.81%) articles respectively. Bangladesh was ranked at 3rd place in terms of total articles but in terms of SP, FP and RP it was ranked at 6th place. S and SP for Indian articles are very high which indicates that India produced most independent articles. There were only two countries (India and Bangladesh) located in the River Ganga basin contributed a total of 1339 (77.96%) number of articles.

Table 3. Top 10 Most Productive Countries (1991-2016)

Country	TP	TP R (P)	SP R (P)	CP R (P)	S	FP R (P)	RP R (P)
India	1162	1 (57.81)	1 (64.25)	1 (44.93)	74.1	1 (49.7)	1 (49.25)
USA	405	2 (20.15)	2 (11.57)	2 (37.31)	38.27	2 (13.88)	2 (14.13)
Bangladesh	177	3 (8.81)	6 (2.01)	3 (22.39)	15.25	6 (3.03)	6 (2.74)
UK	170	4 (8.46)	4 (2.54)	4 (20.3)	20	3 (4.98)	3 (5.27)
Japan	153	5 (7.61)	3 (3.13)	6 (16.57)	27.45	4 (4.83)	4 (4.98)
Germany	138	6 (6.87)	8 (1.72)	5 (17.16)	16.67	5 (3.23)	5 (2.99)
France	104	7 (5.17)	5 (2.24)	7 (11.04)	28.85	7 (2.99)	7 (2.69)
Peoples R China	81	8 (4.03)	7 (1.87)	8 (8.36)	30.86	8 (2.34)	8 (2.34)
Australia	60	9 (2.99)	11 (0.75)	9 (7.46)	16.67	10 (1.29)	10 (1.29)
Netherlands	56	10 (2.79)	10 (1.19)	10 (5.97)	28.57	9 (1.64)	9 (1.64)
TP Total articles; *R* Rank; *P* Percentage; *SP* Single country articles; *CP* Internationally collaborative articles; *FP* First author articles; *RP* Corresponding author articles; *S* Percentage of single country articles out of the total articles for each country							

Table 4. Top 10 Most Productive Institutions

	TP	TP R (P)	SP R (P)	CP R (P)	FP R (P)	S	RP R (P)
Indian Institute of Technology	193	1 (9.6)	1 (8.05)	1 (10.75)	1 (6.57)	35.75	1 (6.32)
Lucknow University	70	2 (3.48)	5 (2.45)	2 (4.25)	3 (2.19)	30	3 (2.19)
Banaras Hindu University	68	3 (3.38)	3 (3.03)	3 (3.64)	3 (2.19)	38.24	2 (2.24)
Physical Research Laboratory India	56	4 (2.79)	6 (2.22)	4 (3.21)	5 (1.74)	33.93	5 (1.69)
Aligarh Muslim University	55	5 (2.74)	2 (4.32)	5 (1.56)	2 (2.34)	67.27	4 (2.09)
Jawaharlal Nehru University	54	6 (2.69)	4 (2.68)	6 (2.69)	6 (1.64)	42.59	6 (1.59)
Wadia Institute of Himalayan Geology	49	7 (2.44)	8 (1.87)	7 (2.86)	8 (1.44)	32.65	9 (1.39)
Jadavpur University	44	8 (2.19)	7 (1.98)	8 (2.34)	7 (1.54)	38.1	7 (1.54)
University of Calcutta	42	9 (2.09)	10 (1.75)	9 (2.34)	9 (1.39)	35.71	8 (1.44)
University of Dhaka	39	10 (1.94)	#N/A	10 (3.38)	107 (0.15)	0	267 (0.05)

TP Total articles; R Rank; P Percentage; SP Single institution articles; CP Inter-institutionally collaborative articles; FP First author articles; RP Corresponding author articles; S Percentage of the single institution articles out of the total articles of each institution

Table-4 highlights the top ten most prolific institutions as per the number of the articles published on River Ganga. Among the top ten institutions first nine institutions are located in India while the tenth ranked institute is in Bangladesh. From the results of the study the IIT's have been found at the top in terms of "total articles, single institute articles, Inter institutional collaborative articles, first author articles, and corresponding articles." Aligarh Muslim University being at the fifth rank (55; 2.745) had second highest independent research publications and articles with first authors. Although the Indian Institute of Technology occupies the top place with 193 articles constituting 9.6% of the total publications. The tally includes the publications from 23 branches of IITs, spread over different states. In view of the fact, Lucknow University that otherwise occupies second position, may be considered as the leading contributor.

Authorship

Author analysis of the publications was carried out on the basis of different Bibliometric indicators namely "total publications, single authored articles, collaborative authored articles, first authored articles, and corresponding authored articles." Table 5 illustrates the 9 most prolific authors for their total publications. However, as noted by Zuckerman 1968; Costas and Bordons 2011, first and the last are considered to be most important positions. France-Lanord C from "Centre National de la Recherche Scientifique of Nancy, France" and Singh IB from Lucknow University, India are leading contributors with 36 articles each. Out of the top ten authors, seven are from the Indian institutes, while others are from France, and Bangladesh. From the overall analysis of the authorship Hossain MY, from Rajshahi University, Bangladesh is the only author having more first authored publications (21) out of his 22 contributed articles.

Table 5. Nine most productive authors

Authors	Institute	TP	TP R (P)	SP	CP	FP	RP
France-Lanord C	Centre National de la Recherche Scientifique (CNRS), CNRS: Vandoeuvre les Nancy, France	36	36 (1.78)	0	36	0	0
Singh IB	Lucknow University, India	36	36 (1.78)	0	36	5	7
Sinha R	Indian Inst Technol, Kanpur	29	29 (1.44)	1	28	11	16
Singh, Sunil Kumar	Physical Research Laboratory, Ahmedabad, India	26	26 (1.29)	0	26	6	5
Hossain MY	Rajshahi University, Bangladesh	22	22 (1.09)	1	21	21	21
Chakrapani GJ	Indian Institute of Technology (IIT) - Roorkee, India	20	20 (0.99)	2	18	8	8
Umar R	Aligarh Muslim University, India	19	19 (0.94)	1	18	9	12
Shukla UK	Banaras Hindu University, Varanasi, India	18	18 (0.89)	1	17	10	9
Subramanian V	Jawaharlal Nehru University, India	18	18 (0.89)	1	17	2	4
TP Total number of articles; *R* Rank; *FP* First author articles; *RP* corresponding authored articles; *SP* Single authored articles							

Table 6. Ten Most Frequently Cited River Ganga Articles (TC2016>250)

| TC2016(R)	C2016(R)	C0(R)	
590 (1)	59 (6)	3 (42)	Islam, F. S., Gault, A. G., Boothman, C., Polya, D. A., Charnock, J. M., Chatterjee, D., & Lloyd, J. R. (2004). Role of metal-reducing bacteria in arsenic release from Bengal delta sediments. *Nature*, *430*(6995), 68–71. https://doi.org/10.1038/nature02638
577 (2)	138 (1)	4 (25)	Immerzeel, W. W., van Beek, L. P. H., & Bierkens, M. F. P. (2010). Climate Change Will Affect the Asian Water Towers. *Science*, *328*(5984), 1382–1385. https://doi.org/10.1126/science.1183188
552 (3)	34 (13)	2 (86)	Berg, M., Tran, H. C., Nguyen, T. C., Pham, H. V., Schertenleib, R., & Giger, W. (2001). Arsenic contamination of groundwater and drinking water in Vietnam: A human health threat. *Environmental Science & Technology*, *35*(13), 2621–2626. https://doi.org/10.1021/es010027y
483 (4)	81 (2)	0 (493)	Singh, K. P., Malik, A., Mohan, D., & Sinha, S. (2004). Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India) - a case study. *Water Research*, *38*(18), 3980–3992. https://doi.org/10.1016/j.watres.2004.06.011
462 (5)	43 (8)	1 (191)	Lave, J., & Avouac, J. P. (2000). Active folding of fluvial terraces across the Siwaliks Hills, Himalayas of central Nepal. *Journal of Geophysical Research-Solid Earth*, *105*(B3), 5735–5770. https://doi.org/10.1029/1999JB900292
448 (6)	37 (10)	4 (25)	McArthur, J. M., Ravenscroft, P., Safiulla, S., & Thirlwall, M. F. (2001). Arsenic in groundwater: Testing pollution mechanisms for sedimentary aquifers in Bangladesh. *Water Resources Research*, *37*(1), 109–117. https://doi.org/10.1029/2000WR900270
390 (7)	25 (20)	2 (86)	Bilham, R., Larson, K., Freymueller, J., Jouanne, F., LeFort, P., Leturmy, P., … deVoogd, B. (1997). GPS measurements of present-day convergence across the Nepal Himalaya. *Nature*, *386*(6620), 61–64. https://doi.org/10.1038/386061a0

330 (8)	18 (34)	1 (191)	Chung, S. L., Lo, C. H., Lee, T. Y., Zhang, Y. Q., Xie, Y. W., Li, X. H., … Wang, P. L. (1998). Diachronous uplift of the Tibetan plateau starting 40 Myr ago. *Nature*, *394*(6695), 769–773. https://doi.org/10.1038/29511
293 (9)	17 (39)	4 (25)	Palmer, M., & Edmond, J. (1992). Controls Over the Strontium Isotope Composition of River Water. *Geochimica Et Cosmochimica Acta*, *56*(5), 2099–2111. https://doi.org/10.1016/0016-7037(92)90332-D
278 (10)	50 (7)	3 (42)	Dai, A., Qian, T., Trenberth, K. E., & Milliman, J. D. (2009). Changes in Continental Freshwater Discharge from 1948 to 2004. *Journal of Climate*, *22*(10), 2773–2792. https://doi.org/10.1175/2008JCLI2592.1

TC2016 Total number of citations till 2016; *R* Rank; *C2016* Number of citations in 2016; *C0* Number of citations in publication year of the articles

Impact of Most Frequently Cited Articles:

Articles having maximum number of total citations from the year 1991 till 2016 can be regarded as the main articles in the field of study. Table 6 highlights top 10 mostly cited articles having *TC2016>250*, out of which three articles were published in *'Nature'* Journal. Article titled "Role of metal-reducing bacteria in arsenic release from Bengal delta sediments (Islam et al. 2004)," published in *'Nature'* Journal by seven authors from India and UK occupies the top position with the maximum citations *(TC2016=590)*. Other articles ranking from 2 to 10 positions were published by the countries USA (3), UK (2), India (2), Taiwan (1), Vietnam (1), Switzerland (1), France (1), Bangladesh (1), Peoples R China (1), and Netherland (1). The top ten articles by TC2016 couldn't found the same place in *C2016* nor in *CO2016*. The citations of the top five articles (TC2016>400) are shown in Figure 2.

Figure 2 Top 6 Most Cited Articles and Their Citation Life Cycles (TC2016>400)
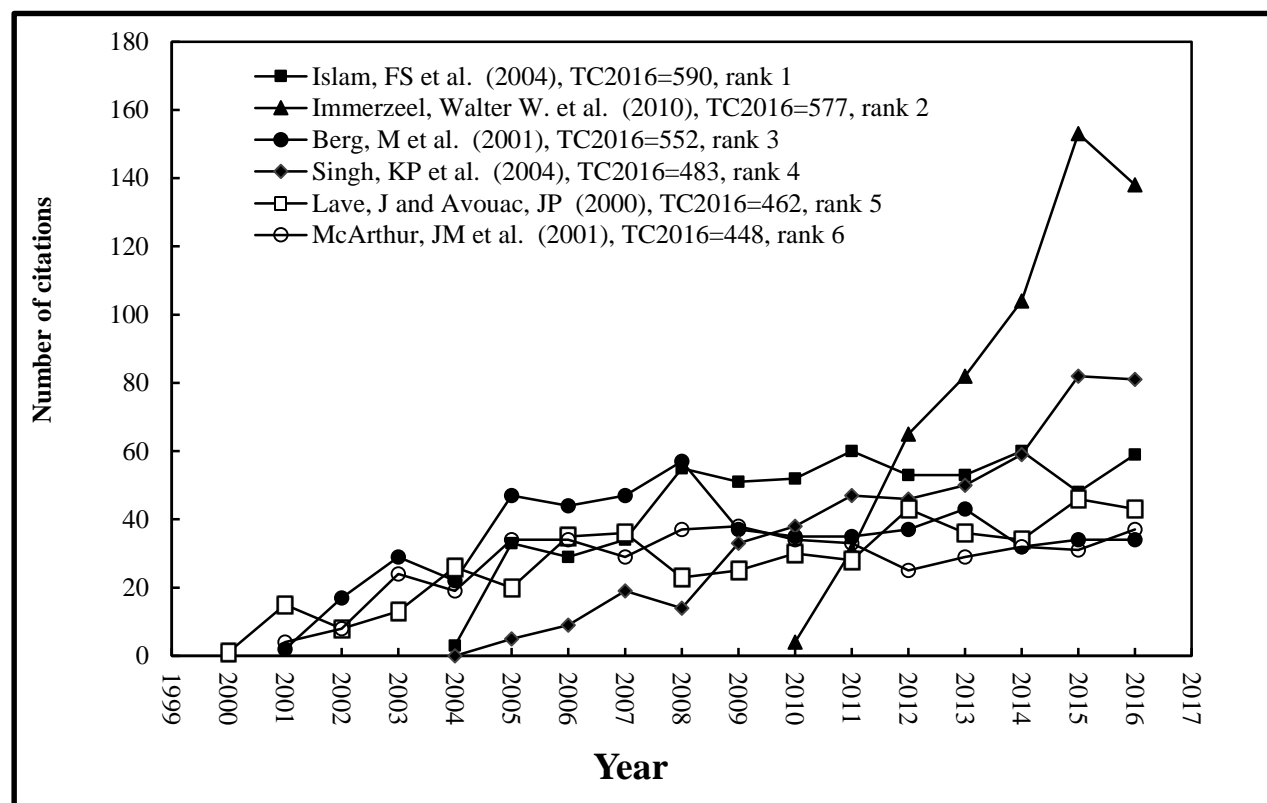
Author Keywords

Author keywords analysis of 2017 articles under the purview indexed in SCI database from 1991 to 2016 (16 years) was carried out. It was found that a total number of 4496 keywords were used by the authors, out of which 3616 keywords comprising 80.43% to the total were used once and remaining 19.57% were used more than once. Table 7 shows the top 20 mostly used author keywords in which India occupies top rank with 97 articles i.e. 6.72% of the total articles, followed by Bangladesh (88), Arsenic (83), Ground water (69), Himalaya (57), Climate change (45), Ganga Plain (43), Ganges (42), and the last on the 20th rank is 'Climate' which occurs in 24 articles, i.e. 1.39% of the total.

Table 7. Author keywords for each paper related to Ganga River

Author keywords	TP	R (%)	Author Keywords	R (%)
India	97	1 (6.72)	Remote Sensing	13 (2.08)
Bangladesh	88	2 (6.09)	Himalayas	14 (1.94)
Arsenic	83	3 (5.75)	Ganges River	15 (1.8)
Groundwater	69	4 (4.78)	Ganga Basin	16 (1.59)
Himalaya	57	5 (3.95)	Weathering	16 (1.59)
Climate change	45	6 (3.12)	Sediment	18 (1.52)
Ganga Plain	43	7 (2.98)	Ganga	18 (1.52)
Ganges	42	8 (2.91)	River Ganga	18 (1.52)
Heavy metals	39	9 (2.7)	Thlaspi Caerulescens	18 (1.52)
Water quality	34	10 (2.35)	Monsoon	22 (1.45)
Ganga River	32	11 (2.22)	Cadmium	22 (1.45)
Bay of Bengal	31	12 (2.15)	Climate	24 (1.39)
TP Total articles; *R* Rank; *P* Percentage of the total articles				

CONCLUSION

As per the data collected from WoS, a total of 2017 articles from 1991-2016 were published in 547 journals among 110 subject categories. The analysis of the data taking different indicators into consideration showed that: India is the country with maximum research output followed by USA, Bangladesh, UK, and Japan. It has been found that contribution of USA under every parameter of the present study is significant. The analysis of 2017 articles published reveals that Indian authors were the leading contributors to the total research output, in which Indian Institute of technology have played a great part, followed by Lucknow University and Banaras Hindu University respectively. In addition to this, keyword analysis revealed that India occupies top rank with 97 articles i.e. 6.72% of the total articles, followed by Bangladesh (88), Arsenic (83), Ground water (69) etc. The research on River Ganga is not only national in nature rather it is a global one, because its study is in terms of environmental factors, covered as an umbrella term for global preservation of water bodies and its related concepts. It is well known that the amount of research output by any nation with regards to the preservation and management of their water bodies is directly influenced by the policies of that nation.

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